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INTERFERENCE OF A WING AND A JET IN A CARRYING FLOW. (U)
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INTERFERENCE OF A WING AND A JET IN A CARRYING FLOW

by

V. N. Arnol'dov, M. G. Gordon, and A. A. Savinov

FOREIGN TECHNOLOGY DIVISION

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Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yë or ë. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

GREEK ALPHABET

Alpha	Α α α			Nu	Ν ν	
Beta	Β β			Xi	Ξ ξ	
Gamma	Γ γ			Omicron	Ο ο	
Delta	Δ δ			Pi	Π π	
Epsilon	Ε ε ϵ			Rho	Ρ ρ ϱ	
Zeta	Ζ ζ			Sigma	Σ σ ς	
Eta	Η η			Tau	Τ τ	
Theta	Θ θ ϑ			Upsilon	Υ υ	
Iota	Ι ι			Phi	Φ φ ϕ	
Kappa	Κ ϰ κ ϰ			Chi	Χ χ	
Lambda	Λ λ			Psi	Ψ ψ	
Mu	Μ μ			Omega	Ω ω	

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	$\sin^{-1}$
arc cos	$\cos^{-1}$
arc tg	$\tan^{-1}$
arc ctg	$\cot^{-1}$
arc sec	$\sec^{-1}$
arc cosec	$\csc^{-1}$
arc sh	$\sinh^{-1}$
arc ch	$\cosh^{-1}$
arc th	$\tanh^{-1}$
arc cth	$\coth^{-1}$
arc sch	sech^{-1}
arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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INTERFERENCE OF A WING AND A JET IN A CARRYING FLOW.

V. N. Arnol'dov, M. G. Gordon, A. A. Savinov.

Are given the results of the experimental study of jet effect, which escape/ensue at an angle of 90° to pressure side of wing, on the aerodynamic characteristics of the isolated/insulated wings far from screen and near from it. On the basis of calculations and results of the experimental study of the interaction of the jets of the various forms of the initial cross section with the wings of different relative size/dimensions and planform is given the analysis of the reasons, which cause a change in the effective thrust/rod of jets with an increase in the velocity of incident flow and a decrease in the distance of wing of screen. It is shown, that far from screen the external flow about the jet plays the dominant role in a change in the aerodynamic wing characteristics with an increase in the velocity of incident flow, and near from screen essential favorable effect exerts the vortex/eddy shaft, which appears on the surface of screen.

The interference of wing and jet, which escape/ensues at certain angle to its lower surface, leads, as is known, to formation on the wing of the negative lift, which decreases the value of the effective thrust/rod of jet. Simultaneously undergo considerable change other aerodynamic wing characteristics. These changes in the aerodynamic characteristics are obtained especially essentially in a ecrease in the distance of wing of screen and an increase in the velocity of incident flow. The thrust losses of jet, which appear in the absence of incoming flow, are caused by the viscous forces. The jets in this case, involving into motion surrounding air, creates disturbed flow about wing. Because of this on pressure side of wing appear the rarefactions, which decrease the effective thrust/rod of jet. Far from screen these losses are small. A considerable increase in the losses during a decrease in the distance of wing with jet of screen is connected with the formation of the fan jet, which possesses considerably larger ejecting ability, and the approach of wing to this perturbation source [1] - [3].

An increase in the losses of lift and a change in other aerodynamic wing characteristics with jet with an increase in the velocity of incident flow is connected, in the first place, with the

disturbance/perturbations, which appear during the flow about the jet, and, in the second place, possibly, with certain change of its sucking properties in the carrying flow.

In Fig. 1 shown experimental distribution of the pressure, which appears on flat surface during the flow about the rigid cylinder and real jet, normal to this surface, and the calculated distribution of pressure, obtained during the replacement of jet by the system of the arranged/located on its axle/axis flows on the assumption that the interference of wing and jet is caused only by sucking action of jet [4].

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Comparison shows that pressure distribution in the vicinity of real jet according to the character of the arrangement of the zones of the increased and reduced pressure qualitatively analogous with pressure distribution around rigid cylinder is opposite to the calculated distribution of pressure.

However, the amounts of the supplementary lift, which appear from real jet and rigid cylinder, substantially differ from each other. These differences are obtained especially considerably in the range of comparatively low values of the given relation of the

velocity of incident flow to jet velocity $\left(\frac{V_\infty}{V_c}\sqrt{\frac{\rho_\infty}{\rho_c}}=\bar{V}_\infty \bar{V}_{\rho_\infty}\right)$. Real jet, being bent and being expanded, acquires in the carrying flow the complex three-dimensional/space form, very distant from cylinder [5]. It is characteristic that the most considerable change of the size/dimensions of jet in the carrying flow (unlike jet in the flooded space) occurs not its initial section and can cause essential disturbance/perturbations on wing surface.

Fig. 2 gives some results of the approximate computations, which were made for the case of ideal fluid for the purpose of qualitative evaluation of lift increment (in the portions of the thrust/rod of jet), induced on flat surface by cylinder and being expanded solid body, imitating size/dimensions and the form of jet. The calculations show that the being expanded body, which has the elliptic form of cross section with the relation of semi-axes 1:4 and the transverse size/dimension b, taken according to the experimental data [5], causes in comparison with cylinder many times large in value force, especially in the range of comparatively low values of the given relation of velocity of incident flow to jet velocity. This bears out the fact that the form of jet and its change with an increase in the velocity of incident flow play important role in the presence of the interference of wing and jet.

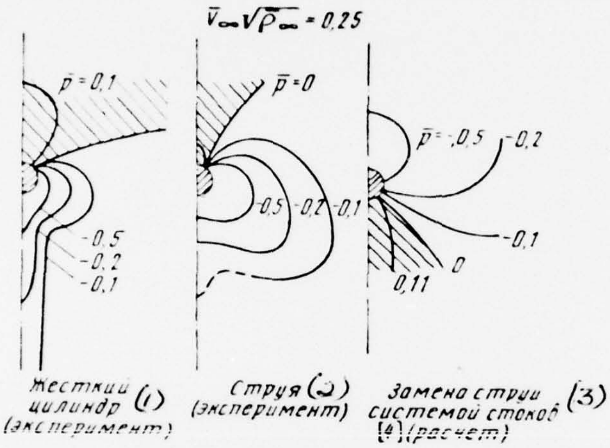

Fig. 1.

Key: (1). Rigid cylinder (experiment). (2). Jet (experiment). (3). Replacement of jet by the system of flows [4] (calculation).

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Moreover, the analysis of these data shows that at the small values of the given velocity ratio the basic disturbance/perturbations on wing are created by the section of the jet of large extent, which possesses lift effectiveness similar to certain low-aspect-ratio wing, arrange/located at high angle of attack with respect to the surface of the main wing. With an increase in the bending of jet the lift effectiveness of its eliminated sections decrease as a result of a decrease in their angle of attack, and increasing value begin to play the disturbance/perturbations, caused by the flow about the initial section of jet as bluff body, close in form to cylinder directly of wing surface. Therefore, for example, a decrease in the initial angle of jet inclination to wing plane leads to an essential decrease in the thrust losses of all range of a change in the given velocity ratio, and at its very large values, when, it would seem, jet is most distant on its form from cylinder, pressure field, induced by circular jet, as shown in work [6], already it differs little not only qualitatively, but also it is quantitative from pressure field in the vicinity of rigid cylinder.

Experimental studies were carried out on the models of rectangular wings with elongation $\lambda = 2$ at angle of attack $\alpha = 0$. Is investigated the interference of wings with the jets, which had in

the initial cross section the form of circle (circular jet) and of the ellipse (elliptical jet), major axis of which can be arrange/located perpendicularly and in parallel to the velocity vector of the incident flow. Subsequently for a convenience let us call elliptical jet depending on the position of its major axis elliptical jet across flow and by elliptical jet along flow.

Far from screen on the wing, which has sufficiently large size/dimensions in comparison with the size/dimensions of the initial jet cross-sectional area $\left(\bar{F}_c = \frac{F_c}{S_{\text{кр}}} = 0{,}00164\right)$, most significant thrust losses gives elliptical across flow, jet, and the jets of round and elliptical along flow form they give close in magnitude of losses (Fig. 3). Fig. 3 shows also the effect of the form of the initial jet cross-sectional area on an increase in the pitching moment of wing.

The elliptical across flow jet (relation of semi-axes equally to 1:10) is bluff in the initial cross sections, but most bent, i.e., it is bluff obstruction, arrange/located on wing surface.

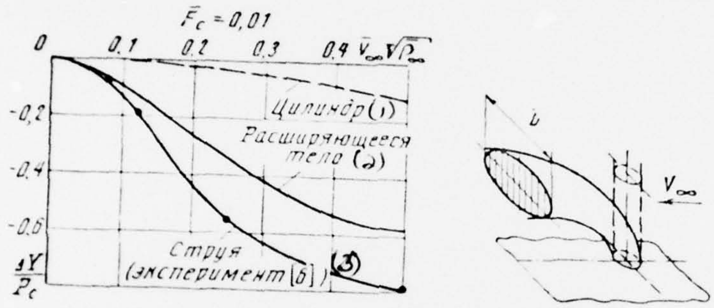

Fig. 2.

Key: (1). Cylinder. (2). Being expanded body. (3). Jet (experiment [6]).

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Even at comparatively small velocities of incident flow the basic disturbance/perturbations on wing are created by its initial section in the form of the vast zones of the elevated pressure before the jet and of evacuation/rarefaction behind jet. The spectra of silk threads

on wing surface show that before the jet occurs braking flow and characteristic boundary-layer separaticn, but after jet is formed vast breakaway zone (Fig. 4).

Elliptical along flow jet is well streamlined on the initial section (narrow trace, the absence of the visible zone of the backwater before the jet). But this jet intensely expanded in transverse direction and is least bent. Experiments in the flooded space show that the characteristic feature of the propagation of elliptical jet is its very nonuniform expansion along the large and minor axes of ellipse. Along minor axis is obtained approximately six times more intense expansion, than on large. During the flow of carrying flow about the jet occurs the supplementary deformation of the form of its cross sections. On the frontal surface of jet appears the overpressure, while on the lateral surfaces and from behind - evacuation/rarefaction.

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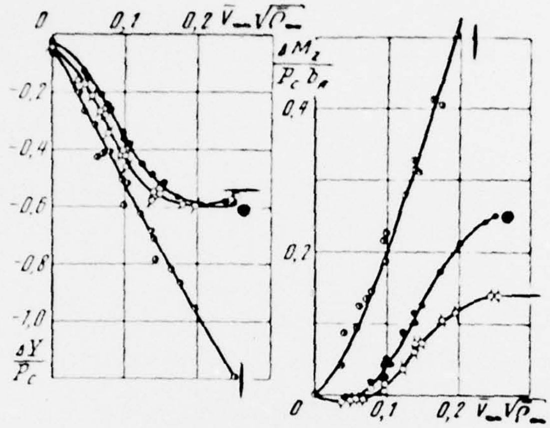

Fig. 3.

$\bar{V}_\infty \sqrt{\bar{\rho}_\infty} = 0,25$

Fig. 4.

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Therefore most significant expansion occurs in the direction, perpendicular to the direction of velocity of incident flow, and elliptical along flow jet at certain removal/distance from wing surface acquires the form, which introduces considerable disturbance/perturbations into flow. The basic disturbance/perturbations on wing surface are created precisely by these sections of jet. They are exhibited predominantly in the formation of rarefaction zones about jet and bear considerably more

uniform character, than disturbance/perturbation from elliptical across flow jet.

Turning again to the results of the tests of rectangular wing with the jets of various forms, which escape/ensue at an angle of 90° to its lower surface (see Fig. 3), it should be noted that they correspond to the representation of the role of the different sections of jet in the formation of losses with an increase in the velocity of incident flow. The imparting to the initial section of the jet of streamlined shape does not lead to a decrease in the thrust losses in the inspected comparatively narrow range of a change in the given velocity ratio. The jets of round and elliptical along flow form cause close in the magnitude of losses of thrust/rod. Consequently, under these mode/conditions is important not so much the form of the initial jet cross-sectional area, as complete three-dimensional/space form of the jet, which is formed n the carrying flow. But it is obtained close of both jets, judging from the fact, that at a distance of five calibers from wing surface they give already approximately identical trace on the grid of silk threads (Fig. 5).

The effect of the form of the initial jet cross-sectional area (or the mutual arrangement of several jets) on aerodynami wing characteristics depends substantially on the ratio of the area of the initial jet cross-sectional area to wing area.

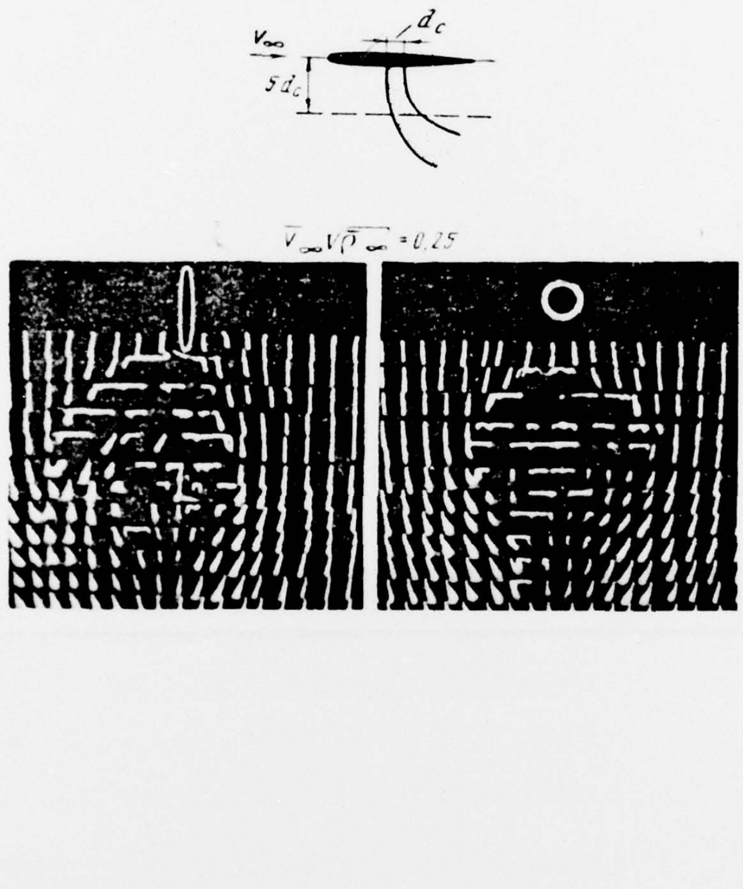

Fig. 5.

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Thrust losses on the rectangular wing of low size/dimensions with jets elliptical across flow and circular shape $(F_c = 0{,}01)$ first increase with an increase in the given velocity ratio, and then, after achieving the greatest value, they decrease and finally $\frac{\Delta Y}{P_c}$ it reverses the sign (Fig. 6). In this case the increase of pitching moment reaches the significant magnitudes. Elliptical jet along flow on low wing as on large, causes thrust losses, which increase during an increase in the given velocity ratio.

The sharp qualitative change in the aerodynamic wing characteristics with the jets of round and elliptical across flow form, which occurs during in the relative size decreases of wing, is connected with the fact that on low rectangular wing part of the zone of the essential disturbance/perturbations, caused by jets, proves to be outside the limits of wing. At certain value of the given relation of the velocities, when appear positive lift increments, the prevailing value acquires the zone of the elevated pressure before the jet, and the rarefaction zone, which appears after jet, it is located partially outside wing. The measurements of the d stribution of pressures on wing surface (for example, [6]) show that with an

increase in the velocity of incident flow gradually is developed the zone of the backwater before the jet during simultaneous decrease in the size/dimensions and displacement downstream of rarefaction zone. It is possible and furthermore manifests itself the jet effect on the flow about the suction side of wing.

During the size decrease of wing with elliptical in flow jet these phenomena do not have vital importance because of the special feature/peculiarities of the disturbance/perturbations, which appear during the flow about this jet, which it was discussed above.

Elliptical across flow jet (or the arrangement of jets in a series across flow) has on low rectangular wing essential advantages in comparison with elliptical along flow jet (or the arrangement of jets in a series in flow). The considerably larger increase of pitching moment, obtained on wing with this jet, allows in certain assigned center-of-gravity location to misalign elliptical across flow jet nearer to trailing wing edge and to obtain for this count supplementary advantages in comparison with elliptical along the flow jet.

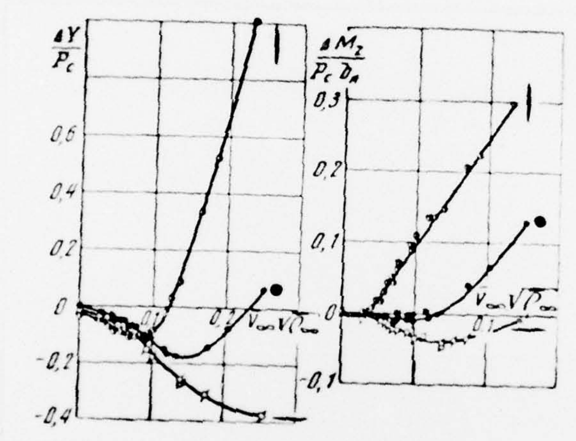

Fig. 6.

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Circular jet also possesses essential advantages in comparison with elliptical along flow jet at the sufficiently large values of the given velocity ratio.

A change in the form of jet or layout of jets on wing allows on the rectangular wings, which have **the close** to real ratio of the area of nozzle to the area of the wing($\bar{F}_c \approx 0{,}01$), not only substantial to decrease the thrust losses, but also tc very considerably increase the effective thrust/rod of jet. This will agree with the results of the investigation of the diverse variants cf the arrangement of nine jets on rectangular wing, given in work [7].

Of the possibilities of using a zone of elevated pressure for a decrease in the thrust losses on the wings cf the limited size/dimensions it depends on wing planform and the position of jets on wing. Thus, for instance, as a result of the special feature/peculiarities of the geometry of delta wing the positive action of the backwater, which appears before the jet, is not utilized, and the effect of diffluences prevails, determining a change in the total aerodynamic characteristics. Therefore on delta wing in a comparatively front/leading position cf jets elliptical across flow jet causes the considerably larger thrust losses than of the jet of round and elliptical along flow form. On themes to reasons the displacement of circular jet to leading wing edge pro uces an essential increase in the thrust losses at the large values of the given velocity ratio.

Thus, far from the Earth the external flow about the jet is the important factor, which determines a change in the aerodynamic wing characteristics with an increase in the velocity of incident flow. A change in the form of jet or arrangement of jets on wing makes it possible to decrease the harmful interference of wing and jet in the carrying flow.

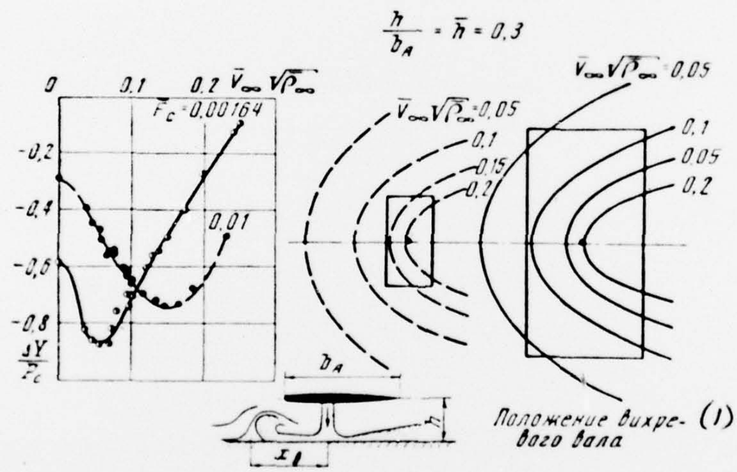

Fig. 7.

Key: (1). Position of the vortex shaft.

The proximity of the Earth considerably complicates the picture of the interaction of the jet of wing and it exerts a substantial influence on aerodynamic wing characteristics with jet. From the diversity of the factors, which determine the interference of wing and jet near the Earth, it is expedient to separate three basic phenomena, which consecutively can occur with an increase in the velocity of incident flow.

First, the formation of the fan jet, which possesses considerably larger ejecting ability, than free jet, and the approach/approximation of wing to this perturbation sourc , the causing increase in the thrust losses. This effect is basic at velocity of incident flow, equal to zero, and it plays significant role at comparatively low values of the given velocity ratio.

In the second place, the formation of the vortex/eddy shaft, which appears during braking fan jet by the incident flow The displacement of shaft with an increase in the velocity of incident flow brings, beginning with certain value of the given relation of velocities, to a decrease in the thrust losses, since before ruby-colored during its flow it appears the zone of elevated pressure, and the sucking action of fan jet it decreases as a result

of in its size decreases. If we compare the position of vortex/eddy shaft with a change in the thrust losses with an increase in the given velocity ratio, then it is not difficult to establish that a decrease in the thrust losses begins when the more or less significant part of the wing proves to be in the zone of the backwater before the shaft (Fig. 7). It is natural that with a decrease in the relative size/dimensions of wing or an increase F_c the positive effect of vortex/eddy shaft is exhibited less considerably. This effect depends also on wing planform, the position of jet on wing and the angle of deflection of jet.

And finally thirdly, the usual proximity effect of the Earth, which becomes the basic effect at sufficiently high velocity of incident flow, when jet is bent so, that the vortex/eddy shaft does not appear. As an example it is possible to give the results of the tests of rectangular wing with elliptical across flow jet (Fig. 8).

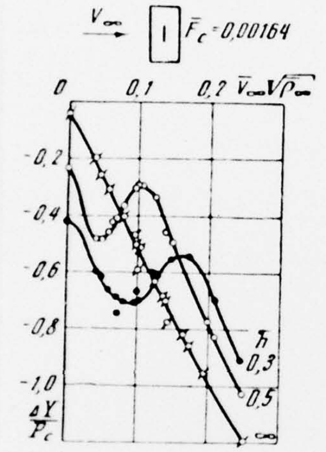

Fig. 8.

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In the range of the low values of the given velocity ratio are observed the same special feature/peculiarities of the course of

dependence $\frac{\Delta Y}{P_c}(V_\infty \sqrt{\rho_\infty})$, that also in the examined previously examples (losses first increase, they reach maximum and then they decrease). At a further increase in the given velocity ratio is reached the minimum of thrust losses, connected with the liquidation of vortex/eddy shaft on the surface of the Earth. The value of the given velocity ratio, by which occurs the liquidation of vortex/eddy shaft, increases during a decrease in the relative distance of wing of the Earth.

Thus, the substantial change in the aerodynamic wing characteristics with jet near the Earth, which occurs with an increase in the velocity of incident flow, is connected with emergence, displacement and finally by the liquidation of vortex/eddy shaft. The favorable effect of shaft can be used for a decrease in the harmful interference of wing and jet near the Earth.

REFERENCES

1. Seibold W. Untersuchungen über die von Hubstrahlen an Senkrechtstarten erzeugten Sekundärkräfte. Jahrbuch 1962 der WGLR, 1963.

2. Wyatt L. A. Static tests on ground-effect on planform fitted with a centrally-located round lifting jet. ARC CP, № 749, 1962.

3. Yakovlevskiy, O. V.; Sekundov, A. N. "Study of the interaction of a jet with close shields." Izv. AN SSSR, Ser.

22

"Mekhanika i mashinostroyeniye", No. 1, 1964.

4. Taganov, G. I. "The theory of the suction action of a jet in transverse flow." Trudy TsAGI, iss. 1172, 1969.

5. Palatnik, I. B.; Temirbayev, D. Zh. "Rules of the propagation of an axisymmetric air jet in a carrying uniform flow." Problemy teploenergetiki i prikladnoy teplofiziki, iss. 4, 1967.

6. Bradbury L. J. S., Wood M. N. Pressure distribution around a circular jet exhausting normally from a plane wall into an airstream. ARC CP. № 822, 1965.

7. Williams J., Wood M. N. Aerodynamic interference effects with jet-lift V/STOL aircraft uder static and forwardspeed conditions. ZFW, Hf. № 7, 1967.

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